# ITRI613 Databases I

*Chapter 2 – Database Design*

# Learning outcomes

After engaging with the materials and activities in this study unit you should be able to:

- give an overview of the design steps of a database and compare them to the levels of abstraction of a DBMS;
- draw an ER diagram according to the specifications or needs of a database in order to have a model that reflects reality as accurately as possible.

# Steps in DB design

- Requirements analysis
- Conceptual DB design
- Logical DB design
- Schema refinement – normalization
- Physical design (indexes)
- Application and security design (roles)

- NOTE: in practice all six steps of design are interleaved and repeated until the design is satisfactory

# Overview of Database Design- Requirements analysis

- understand
  - what data is to be stored in the database,
  - what applications must be built on top of it, and
  - what operations are most frequent and subject to performance requirements

= we must find out what the users want from the database

# Overview of Database Design- Conceptual database design

- using an ER model to develop a high-level description of the data to be stored in the database, along with the applicable constraints
- this facilitates discussion among all the people involved in the design process, even those who have no technical background and
- enable a easy translation into a relational model supported by a commercial database

3 tasks:

- Context data model
- Key-based data model
- Fully attributed data model

# Overview of Database Design- Conceptual database design

- <u>*Conceptual design*</u>: *(ER Model is used at this stage.)*
  - What are the *entities* and *relationships* in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the *integrity constraints* or *business rules* that hold?
  - A database `schema' in the ER Model can be represented pictorially (*ER diagrams*).
  - Can map an ER diagram into a relational schema.

# Overview of Database Design- Logical database design

- convert the conceptual database design (ER schema) into a relational database schema (logical schema) of the chosen DBMS.

# Overview of Database Design- Schema Refinement

- to analyse the collection of relations in our relational database schema to identify potential problems, and to refine it.
- apply theory of *normalization*

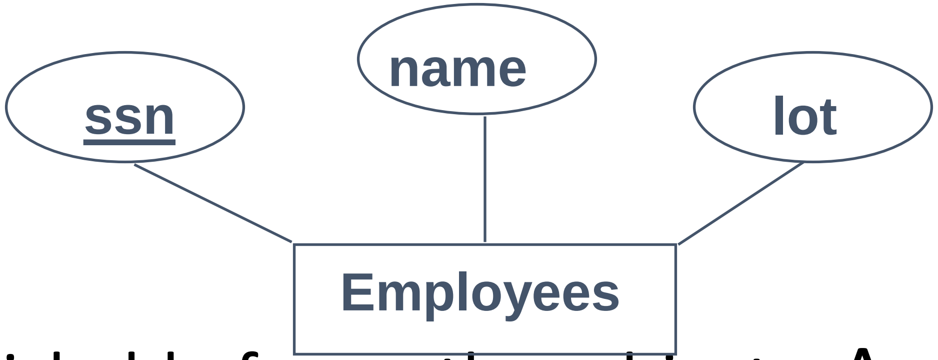
# Overview of Database Design- Physical Database Design

- consider typical expected workloads that our database must support and further refine the database design
- to ensure that it meets desired performance criteria. This step may simply involve building indexes on some tables and clustering some tables, or it may involve a substantial redesign of parts of the database schema obtained from the earlier design steps.
- design the physical schema.

# Overview of Database Design- Application and Security Design

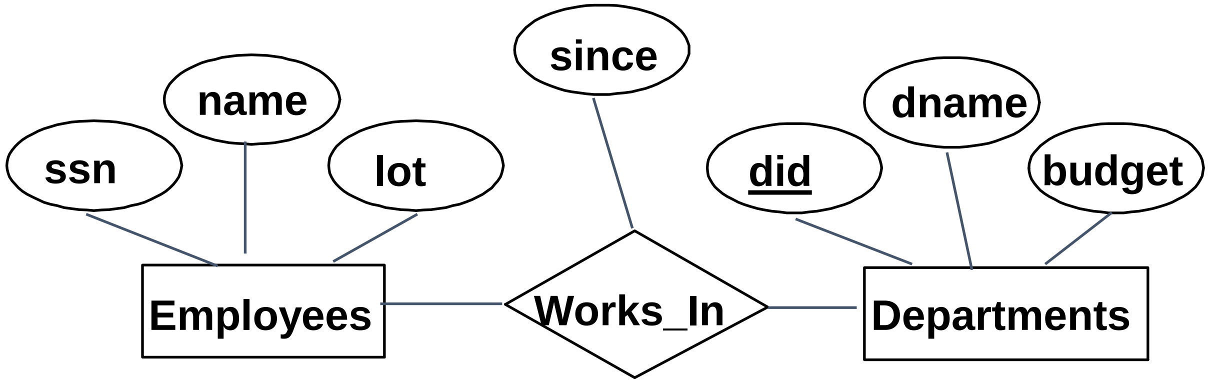
- identify the entities (e.g., users, user groups, departments) and processes involved in the application.
- describe the role of each entity in every process that is reflected in some application task, as part of a complete workflow for that task. For each role, we must identify the parts of the database that must be accessible and the parts of the database that must *not* be accessible, and we must take steps to ensure that these access rules are enforced.
- Therefor ensure that users are able to access the data they need, but not data that we wish to hide from them.

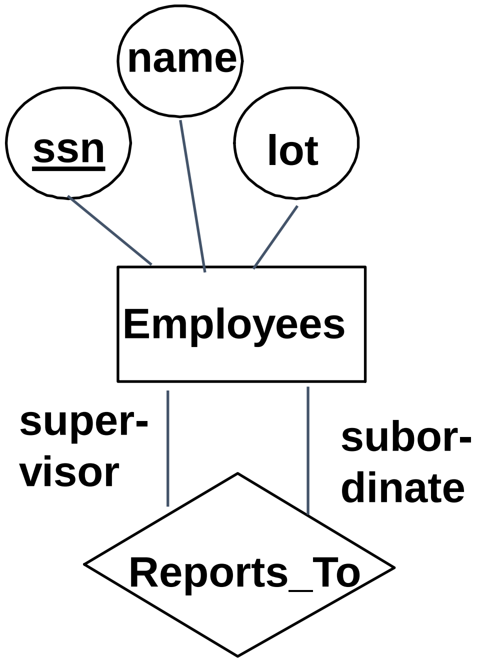
# ER Model Basics




- *Entity:* Real-world object distinguishable from other objects. An entity is described (in DB) using a set of *attributes*.
- *Entity Set*: A collection of similar entities. E.g., all employees.
  - All entities in an entity set have the same set of attributes. (Until we consider ISA hierarchies, anyway!)
  - Each entity set has a *key*.
  - Each attribute has a *domain.*

# ER Model Basics (Contd.)



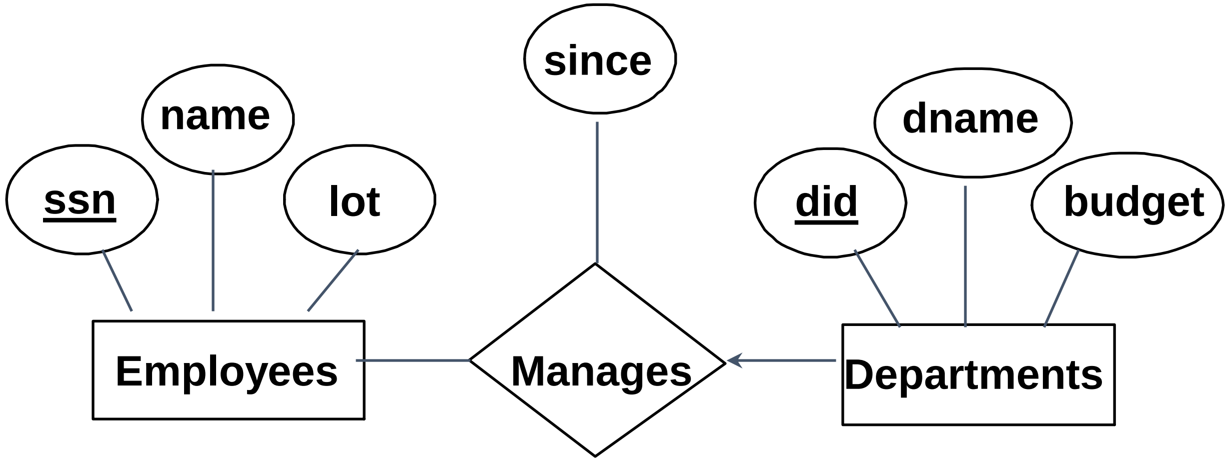

- *Relationship*: Association among two or more entities. E.g., Attishoo works in Pharmacy department. Can be described by descriptive attribute e.g. since
- *Relationship Set*: Collection of similar relationships.
  - An n-ary relationship set R relates n entity sets E1 ... En;

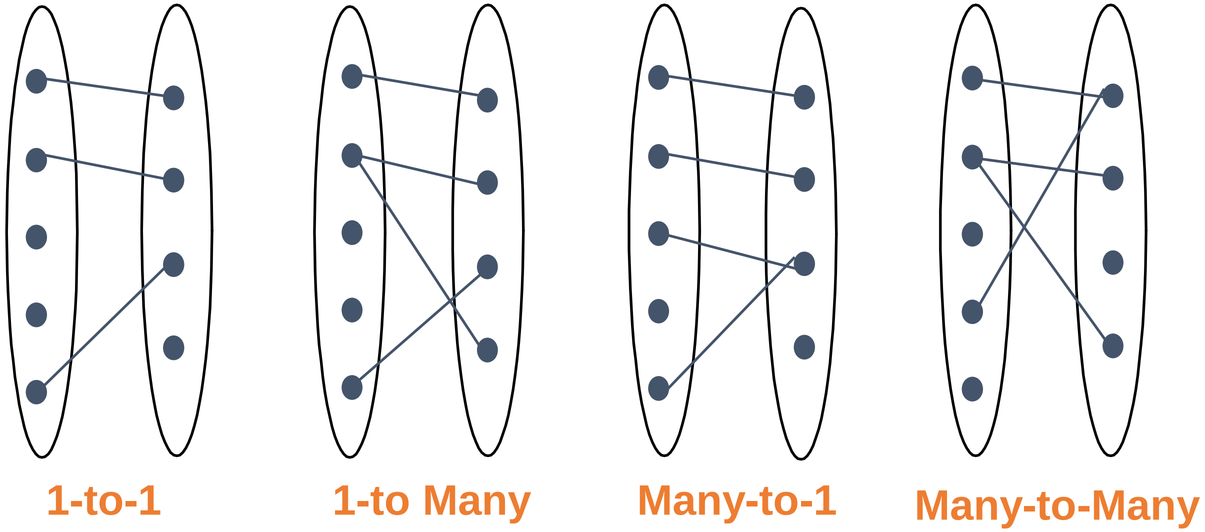
$$\{(e_1, \ldots, e_n) \mid e_1 \in E_1, \ldots, e_n \in E_n\}$$

***UNIQUELY IDENTIFIED BY PARTICIPATING ENTITIES***

# Key Constraints

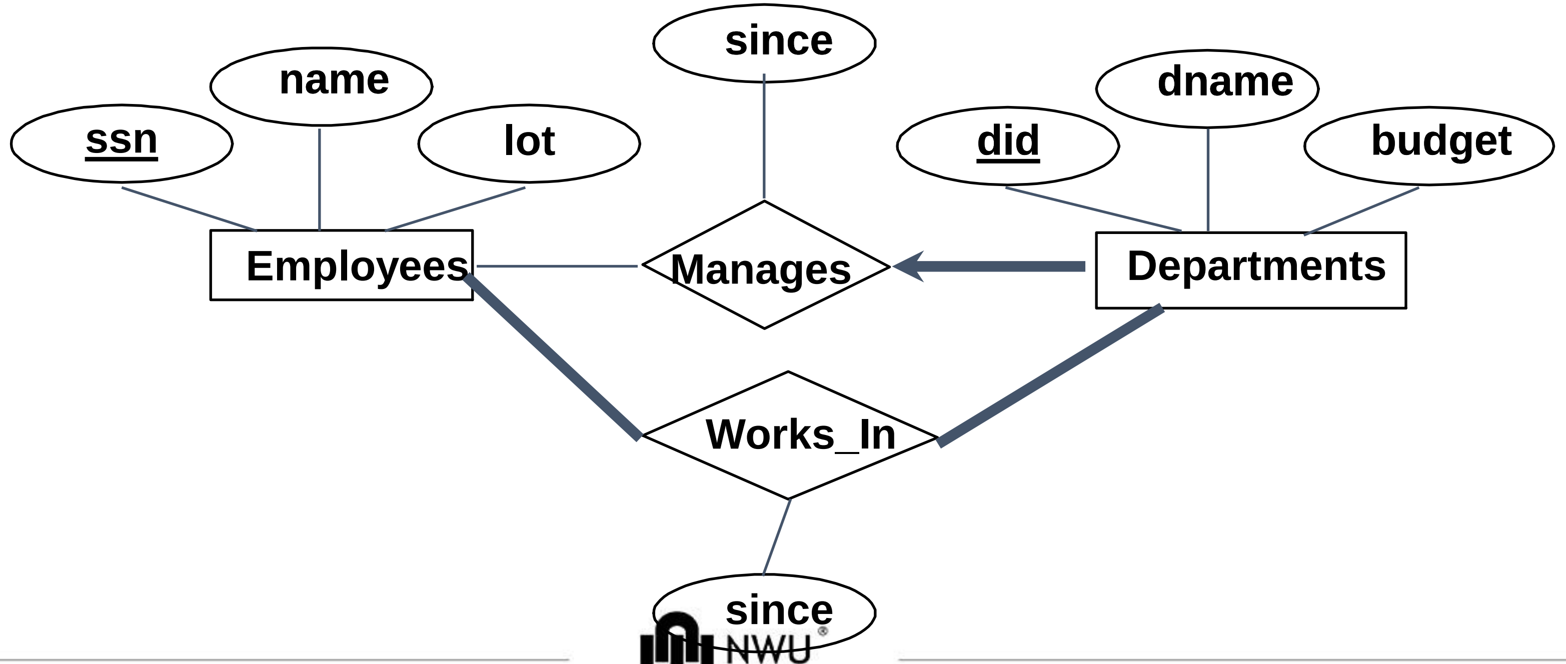
- Consider Manages relationship set: ONE employee can manage MANY departments; ONE dept can have ONE manager.
- This is a *key constraint* on Manages.



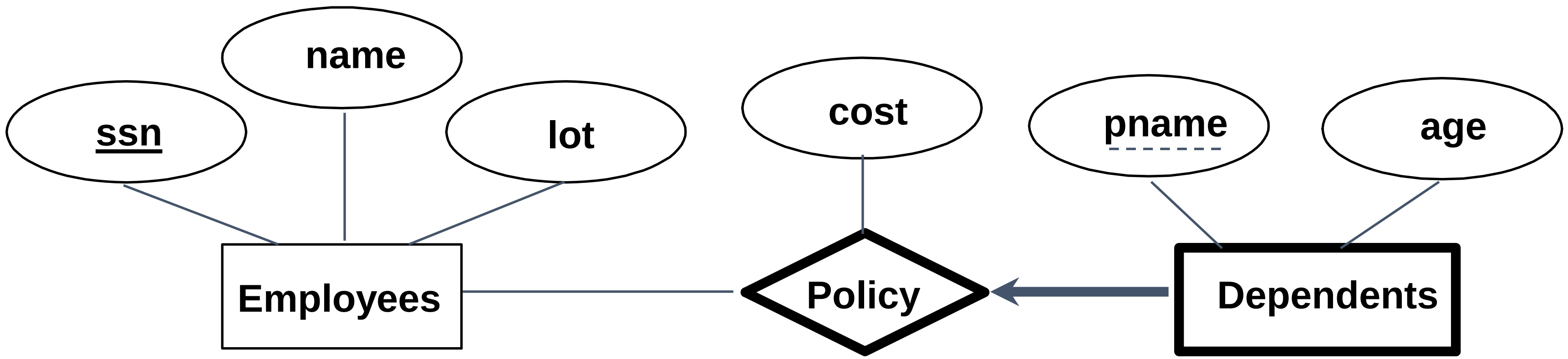
# Participation Constraints

- Does every department have a manager?
  - If so, this is a *participation constraint*: the participation of Departments in Manages is said to be *total* (vs. *partial*).
    - Every Departments entity must appear in an instance of the Manages relationship.
    - The participation condition defines whether it is mandatory or optional for an entity to participate in a relationship.

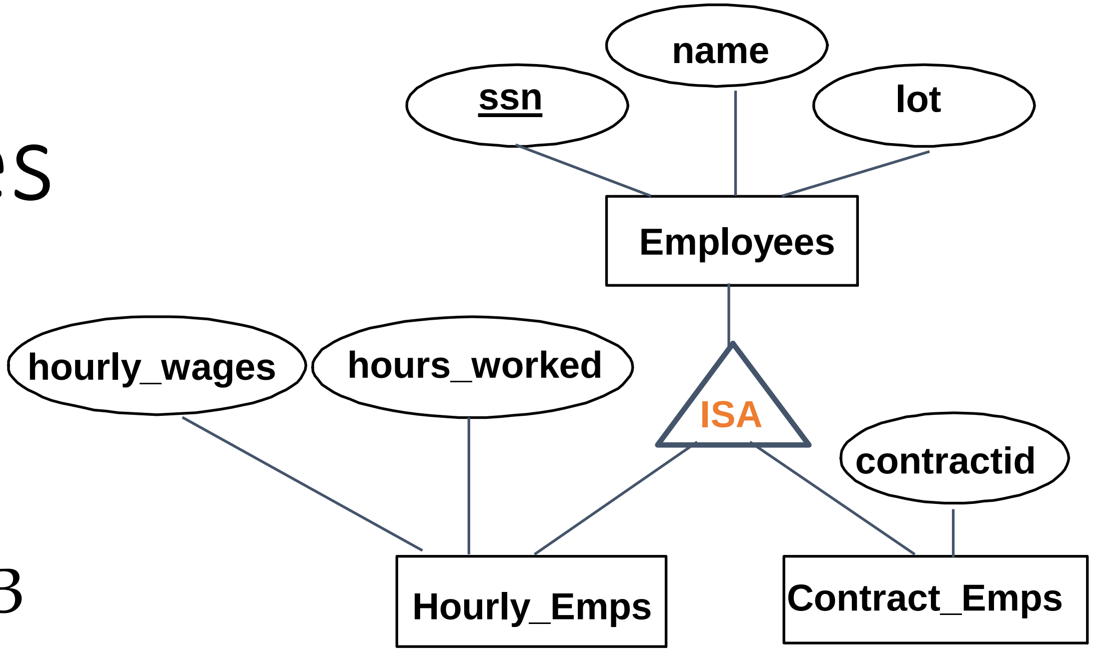


# Weak Entities

- A *weak entity* can be identified uniquely only by considering the primary key of another (*owner*) entity.
  - Owner entity set and weak entity set *must participate in a one-to-many relationship* set (one owner, many weak entities).
  - Weak entity set must have total participation in this *identifying* relationship set.
  - Partial key (broken line); Use BOLD LINES

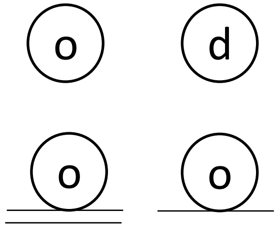


# ISA (`is a’) Hierarchies



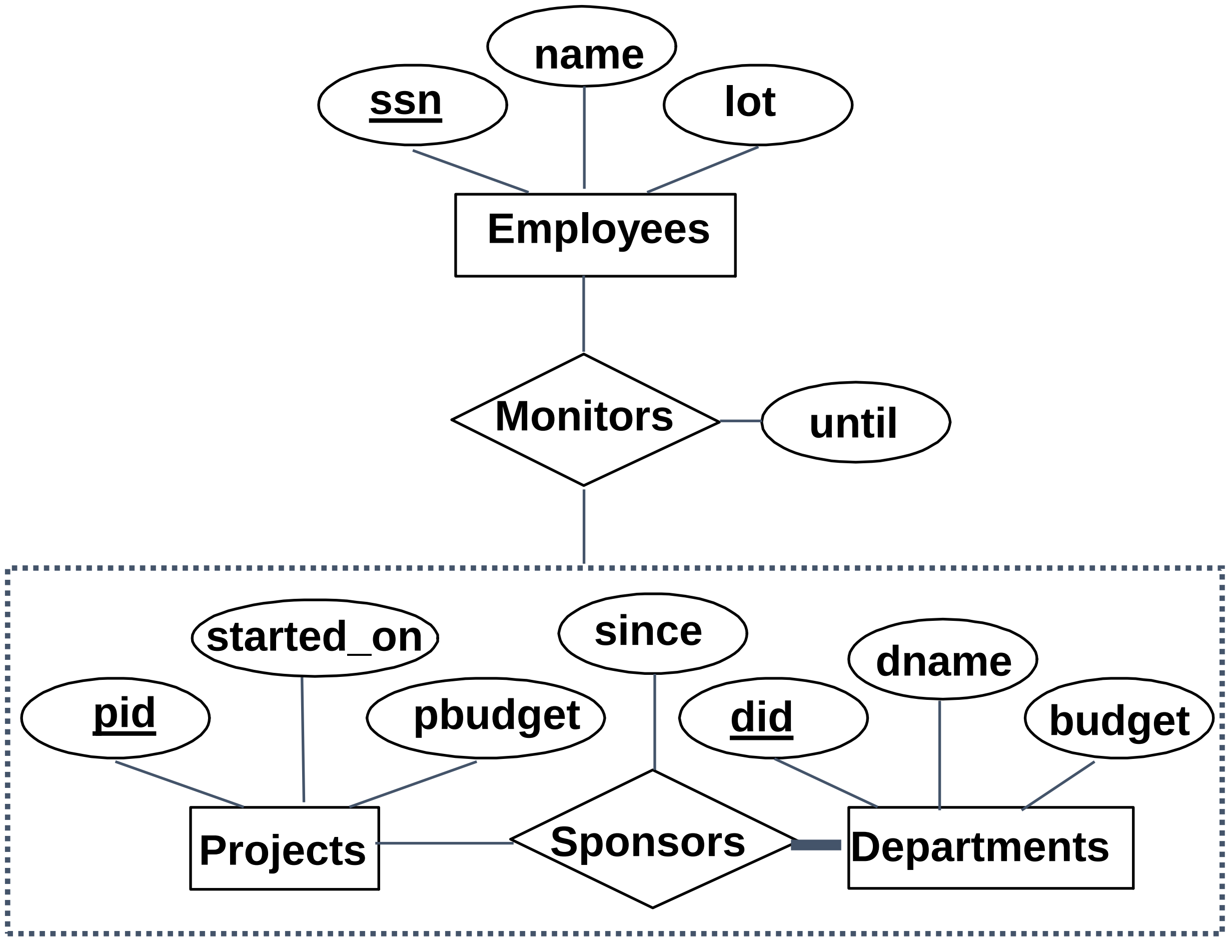

- As in C++, or other PLs, attributes are inherited.
- If we declare A **ISA** B, every A entity is also considered to be a B entity.

- *Overlap constraints*: Can Joe be an Hourly_Emps as well as a Contract_Emps entity? *(Allowed/disallowed)*
- *Covering constraints*: Does every Employees entity also have to be an Hourly_Emps or a Contract_Emps entity? *(Yes/no)*
- Reasons for using ISA:
  - To add descriptive attributes specific to a subclass.
  - To identify entities that participate in a relationship.



# Aggregation

- Used when we have to model a relationship involving (entity sets and) a *relationship set*.
  - *Aggregation* allows us to treat a relationship set as an entity set for purposes of participation in (other) relationships.




* *Aggregation vs. ternary relationship:*

❖ Monitors is a distinct relationship, with a descriptive attribute.

❖ Also, can say that each sponsorship is monitored by at most one employee.

# Conceptual Design Using the ER Model

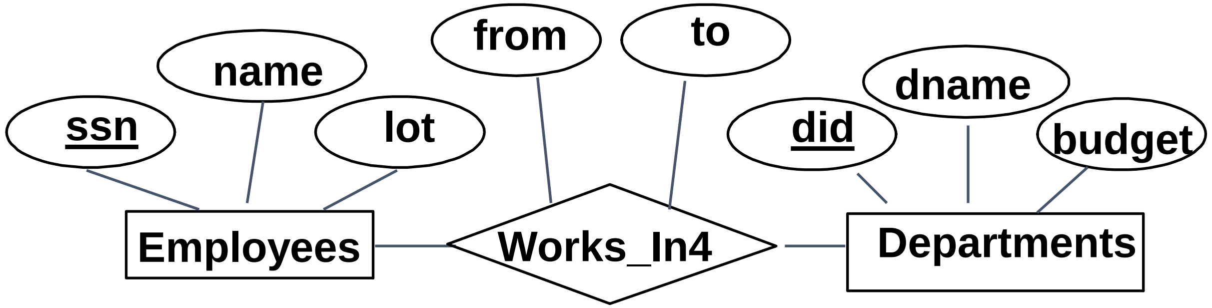
- Design choices:
  - Should a concept be modeled as an entity or an attribute?
  - Should a concept be modeled as an entity or a relationship?
  - Identifying relationships: Binary or ternary? Aggregation?
- Constraints in the ER Model:
  - A lot of data semantics can (and should) be captured.
  - But some constraints cannot be captured in ER diagrams.

# Entity vs. Attribute

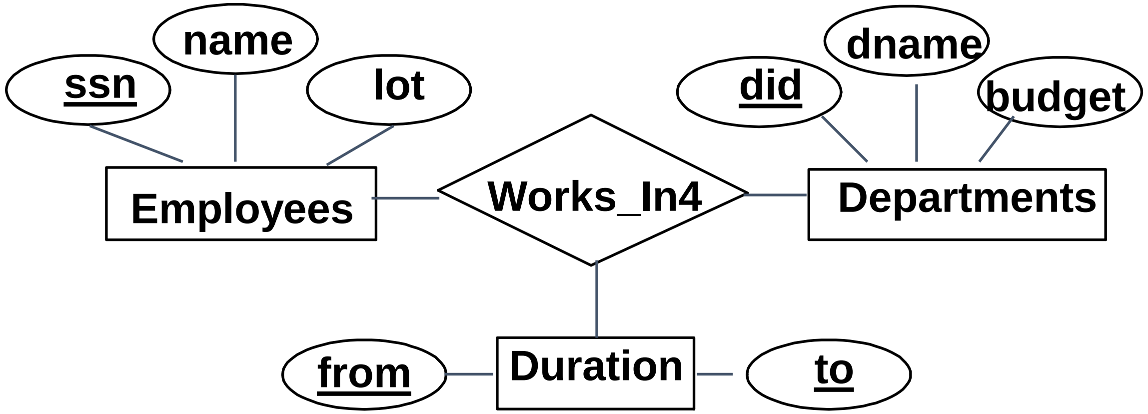
- Should *address* be an attribute of Employees or an entity (connected to Employees by a relationship)?
- Depends upon the use we want to make of address information, and the semantics of the data:
  - If we have several addresses per employee, *address* must be an entity (since attributes cannot be set-valued).
  - If the structure (city, street, etc.) is important, e.g., we want to retrieve employees in a given city, *address* must be modeled as an entity (since attribute values are atomic).

# Entity vs. Attribute (Contd.)

- Works_In4 does not allow an employee to work in a department for two or more periods.

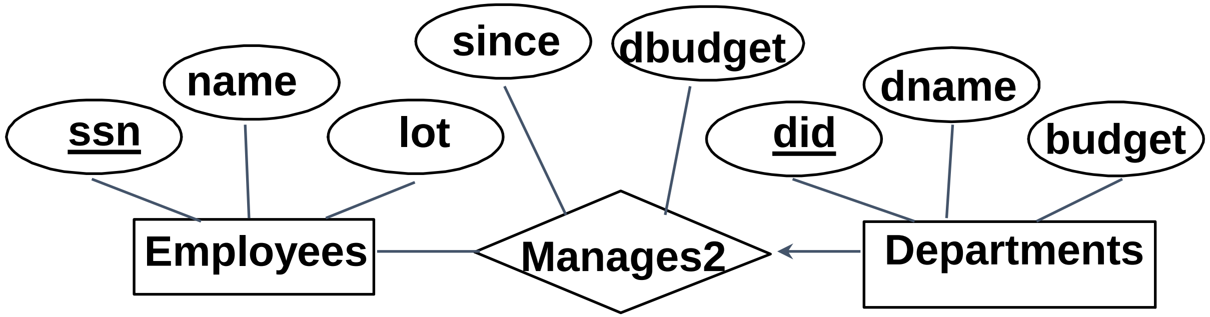


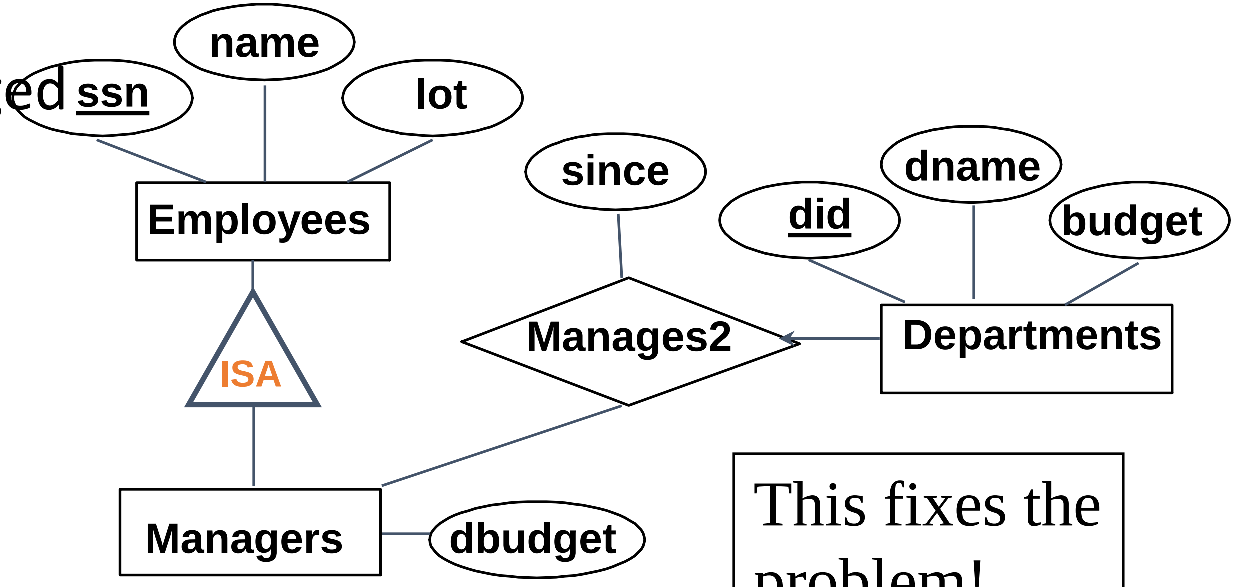

- Similar to the problem of wanting to record several addresses for an employee: We want to record *several values of the descriptive attributes for each instance of this relationship.* Accomplished by introducing new entity set, Duration.



# Entity vs. Relationship

- First ER diagram OK if a manager gets a separate discretionary budget for each dept.
- What if a manager gets a discretionary budget that covers *all* managed depts?
  - Redundancy: *dbudget* stored for each dept managed by manager.
  - Misleading: Suggests *dbudget* associated with department-mgr combination.

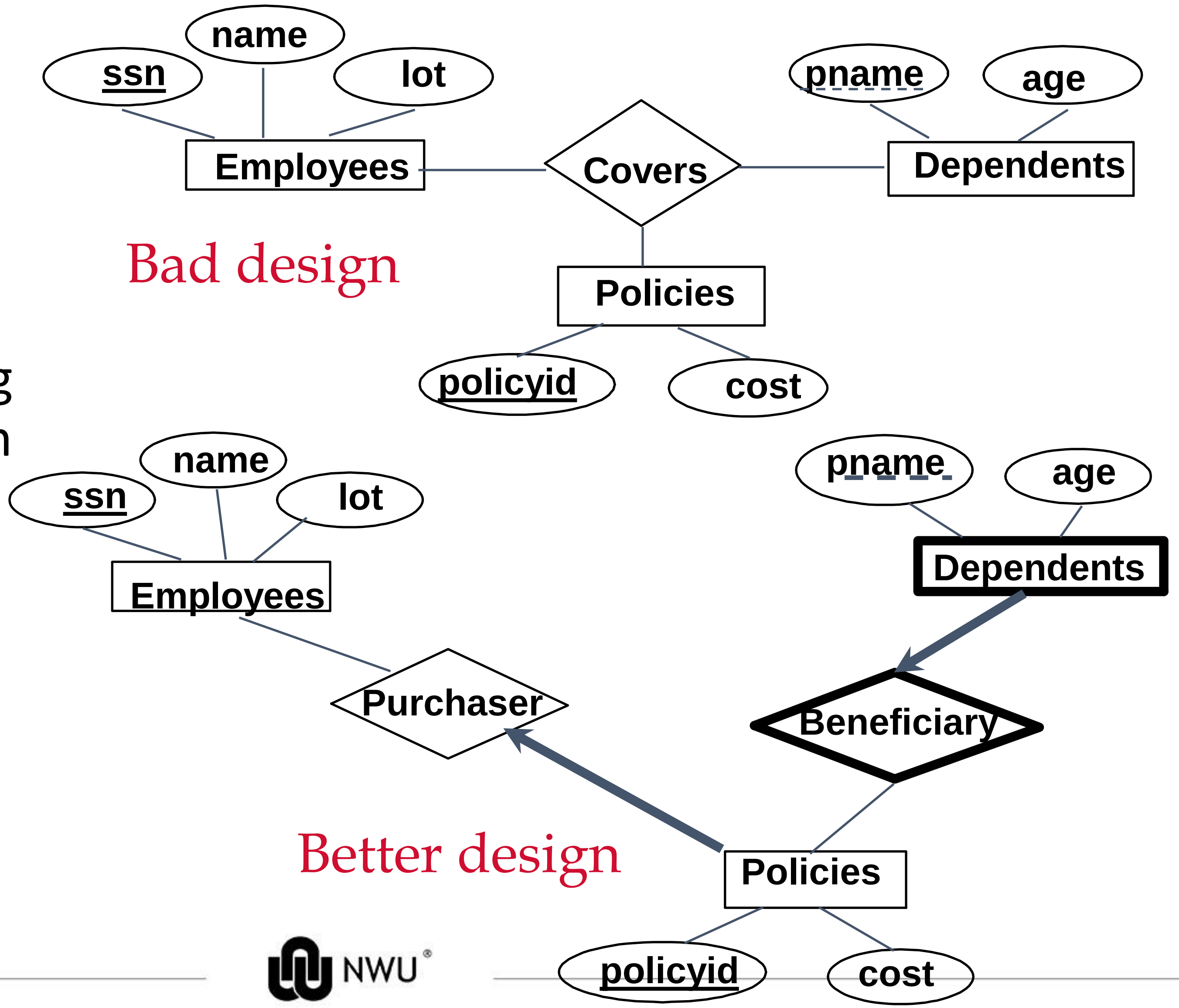



This fixes the problem!

# Binary vs. Ternary Relationships

- If each policy is owned by just 1 employee, and each dependent is tied to the covering policy, first diagram is inaccurate.
- What are the additional constraints in the 2nd diagram?



# Binary vs. Ternary Relationships (Contd.)

- Previous example illustrated a case when two binary relationships were better than one ternary relationship.
- An example in the other direction: a ternary relation Contracts relates entity sets Parts, Departments and Suppliers, and has descriptive attribute *qty*. No combination of binary relationships is an adequate substitute:
  - S “can-supply” P, D “needs” P, and D “deals-with” S does not imply that D has agreed to buy P from S.
  - How do we record *qty*?

# Summary of Conceptual Design

- *Conceptual design* follows *requirements analysis*,
  - Yields a high-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications.
- Basic constructs: *entities*, *relationships*, and *attributes* (of entities and relationships).
- Some additional constructs: *weak entities*, *ISA hierarchies*, and *aggregation*.
- Note: There are many variations on ER model.

# Summary of ER (Contd.)

- Several kinds of integrity constraints can be expressed in the ER model: *key constraints*, *participation constraints*, and *overlap/covering constraints* for ISA hierarchies. Some *foreign key constraints* are also implicit in the definition of a relationship set.
  - Some constraints (notably, *functional dependencies*) cannot be expressed in the ER model.
  - Constraints play an important role in determining the best database design for an enterprise.

# Summary of ER (Contd.)

- ER design is *subjective*. There are often many ways to model a given scenario! Analyzing alternatives can be tricky, especially for a large enterprise. Common choices include:
  - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship, whether or not to use ISA hierarchies, and whether or not to use aggregation.
- Ensuring good database design: resulting relational schema should be analyzed and refined further. FD information and normalization techniques are especially useful.

# Homework

- Library
- Banking
- Ecommerce